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08/952995

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

To:

United States Patent and Trademark Office
(Box PCT)
Crystal Plaza 2
Washington, DC 20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

Date of mailing (day/month/year) 22 January 1998 (22.01.98)	
International application No. PCT/SE97/00887	**Applicant's or agent's file reference** P 97-185/LK
International filing date (day/month/year) 27 May 1997 (27.05.97)	**Priority date** (day/month/year) 29 May 1996 (29.05.96) Jan 98
Applicant LEIJON, Mats et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

22 December 1997 (22.12.97)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was [ ] was not made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer G. Bähr Telephone No.: (41-22) 338.83.38

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PATENT COOPERATION TREATY

REC'D 15 OCT 1998
WIPO PCT

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P97-185/LK/uh		
International application No. PCT/SE97/00887	International filing date (*day/month/year*) 27.05.1997	Priority date (*day/month/year*) 29.05.1996
International Patent Classification (IPC) or national classification and IPC_6 H02K 3/40		
Applicant ASEA BROWN BOVERI AB et al		

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MAR 24 1999
Group 3700

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

☒ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 3 sheets.

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3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
22.12.1997	21.09.1998
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Telex 17978 PATOREG-S Facsimile No. 08-667 72 88	Authorized officer Håkan Sandh Telephone No. 08-782 25 00

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/PCT/SE97/00887

I. Basis of the report

1. This report has been drawn on the basis of *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.)*:

☐ the international application as originally filed.

☒ the description, pages 1-10, as originally filed,
pages ______, filed with the demand,
pages ______, filed with the letter of ______,
pages ______, filed with the letter of ______.

☒ the claims, Nos. ______, as originally filed,
Nos. ______, as amended under Article 19,
Nos. ______, filed with the demand,
Nos. 1-27, filed with the letter of 24.09.1998,
Nos. ______, filed with the letter of ______.

☒ the drawings, ~~sheets~~/fig 1-7, as originally filed,
~~sheets~~/fig ______, filed with the demand
~~sheets~~/fig ______, filed with the letter of ______,
~~sheets~~/fig ______, filed with the letter of ______.

2. The amendments have resulted in the cancellation of:

☐ the description, pages ______
☐ the claims, Nos. ______
☐ the drawings, ~~sheets~~/fig ______

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the supplemental Box (Rule 70.2(c)).

4. Additional observations, if necessary:

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/SE97/00887

V. Resoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-27	YES
	Claims		NO
Inventive step (IS)	Claims	1-27	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-27	YES
	Claims		NO

2. Citations and explanations

The invention relates to an electric plant for high voltage including a motor. The winding of the motor is provided with an insulation system comprising two semiconducting layers with solid insulation in-between.

Documents cited in the International Search Report:

(A) US A 5036165
(B) US A 4429244
(C) SE A 453236
(D) US A 4091139

(A) describes a cable provided with two semiconducting layers with insulation there between. The semiconducting layers include pyrolized organic material and glass fibre. In this document it is suggested that the invented semiconducting layer can be applied to insulated conductors such as a winding in a dynamo-electric machine.

(B) describes a stator with a high-voltage winding for a generator. The insulation of the winding is thick in the bottom of the slot and is then reduced towards the inner periphery of the stator.

(C) and (D) describe high-voltage windings with semiconducting layers.

.../...

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: V

The claimed invention differs from the cited art in that the winding of the machine is provided with an insulation system comprising two semiconducting layers with solid insulation in-between.

Even though it is suggested in document A to apply a semiconducting layer to a winding in a dynamo-electric machine there is no specific indication of using the disclosed cable in a dynamo-electric machine. Further investigating US 4853565, incorporated by reference in document A, the skilled person will find it evident that the invented semiconducting layer is intended to be used on a conventional winding in a machine or in a cable. There is no proposal to use the cable with the insulating system as a winding in an electric machine. Nor can it be considered obvious to a person skilled in the art to use such a cable in a dynamo-electric machine since at the time of the invention it was not known to use a cable with solid insulation as a winding in an electrical machine and there is no teaching in the prior art as a whole that would lead the skilled person to the claimed invention.

Accordingly, the invention claimed is novel and involves an inventive step. The invention is industrially applicable.

AMENDED CLAIMS

1. An electric plant for high voltage consisting of one or more motors, each comprising at least one winding, **characterized** in that the winding of at least one of the electric motors comprises a high-voltage cable having an insulation system comprising at least two semiconducting layers, each layer constituting essentially an equipotential surface, and intermediate solid insulation between the layers.

2. A plant as claimed in claim 1, **characterized** in that at least one motor has one or more connection voltages.

3. A plant as claimed in claim 1 or 2, **characterized** in that at least one of the layers has substantially the same coefficient of thermal expansion as the solid insulation.

4. A plant as claimed in any of claims 1-3, **characterized** in that all transformation of substantial power is arranged to take place in the same electric motor.

5. A plant as claimed in any of claims 1-4, **characterized** in that the insulation is built up of a cable (6) intended for high voltage, comprising one or more current-carrying conductors (31) surrounded by at least two semiconducting layers (32, 34) with intermediate insulating layers (33) of solid insulation.

6. A plant as claimed in claim 5, **characterized** in that the innermost semiconducting layer (32) is at substantially the same potential as the conductor(s) (31).

7. A plant as claimed in either claim 5 or claim 6, **characterized** in that one of the outer semiconducting layers (34) is arranged to form essentially an equipotential surface surrounding the conductor(s) (31).

8. A plant as claimed in claim 7, **characterized** in that said outer semiconducting layer (34) is connected to a predefined potential.

9. A plant as claimed in claim 8, **characterized** in that the predefined potential is earth potential.

10. A plant as claimed in any of claims 5-9, **characterized** in that at least two of said layers have substantially the same coefficient of thermal expansion.

11. A plant as claimed in any of claims 5-7, **characterized** in that the current-carrying conductor comprises a plurality of

strands, only a few of the strands not being insulated from each other.

12. A plant as claimed in any of claims 1-11, **characterized** in that the winding consists of a cable comprising one or more current-carrying conductors (2), each conductor consisting of a number of strands, an inner semiconducting layer (3) being arranged around each conductor, an insulating layer (4) of solid insulation being arranged around each inner semiconducting layer (3) and an outer semiconducting layer (5) being arranged around each insulating layer (4).

13. A plant as claimed in claim 12, **characterized** in that the cable also comprises a metal screen and a sheath.

14. A plant as claimed in any of the preceding claims, **characterized** in that the stator of the motor is cooled at earth potential by means of a flow of gas and/or liquid.

15. A plant as claimed in any of the preceding claims, **characterized** in that the high-voltage cables (6) have a conductor area of between 40 and 3000 mm^2 and have an outer cable diameter of between 10 and 250 mm.

16. A plant as claimed in any of the preceding claims, **characterized** in that the start current and/or fault or current for the rotating electric motor(s) is arranged to be limited by an electric static machine, i.e. a reactor/inductor, which is temporarily and/or permanently connected in series with the armature winding of the rotating electric machine (Figure 4).

17. A plant as claimed in any of the preceding claims, **characterized** in that the neutral point of at least one motor is earthed via an impedance.

18. A plant as claimed in any of the preceding claims, **characterized** in that the neutral point of at least one motor is directly connected to earth.

19. A plant as claimed in any of the preceding claims, **characterized** in that the motor is arranged to operate as producer of reactive power with temporarily large overload capacity.

20. A plant as claimed in any of the preceding claims, **characterized** in that the motor is arranged to be connected to a distribution network or transmission network via coupling elements and without any step-down transforming of the voltage level.

21. A plant as claimed in any of the preceding claims, **characterized** in that the motor is arranged to be connected to a

distribution network or transmission network having a supply voltage in excess of 36 kV.

22. A plant as claimed in any of the preceding claims, **characterized** in that the winding of the motor is arranged for self-regulating field control and lacks auxiliary means for control of the field.

23. An electric plant for high voltage consisting of one or more motors, each of which comprises at least one winding, **characterized** in that the winding of at least one of the electric motors comprises a high-voltage cable having an insulation system which, as regards its thermal and electrical properties, permits a voltage level in excess of 36 kV and in that said motor includes the features defining the plant claimed in any of claims 1-21.

24. An electric motor comprising at least one winding, **characterized** in that the winding comprises a high-voltage cable having an insulation layer including at least two semiconducting layers, each semi-conductor layer constituting essentially an equipotential surface, and intermediate solid insulation.

25. A motor as claimed in claim 24, **characterized** in that its stator winding is divided into two parts in order to achieve partial winding start.

26. A motor as claimed in claim 24 or claim 25, **characterized** in that it has one or more connection voltages.

27. A motor as claimed in any of claims 24-26, **characterized** in that it includes the features defined for the motor in the plant as claimed in any of claims 2-23.

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REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No.

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference (*if desired*) (*12 characters maximum*) P 97-185/LK /uh

Box No. I TITLE OF INVENTION

HIGH VOLTAGE PLANTS WITH ELECTRIC MOTORS

Box No. II APPLICANT

Name and address: (*Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.*)

Asea Brown Boveri AB

S-721 83 VÄSTERÅS
Sweden

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State (*i.e. country*) of nationality: SE

State (*i.e. country*) of residence: SE

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: (*Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.*)

LEIJON, Mats
Hyvlargatan 5
S-723 35 VÄSTERÅS
Sweden

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only (*If this check-box is marked, do not fill in below.*)

State (*i.e. country*) of nationality: SE

State (*i.e. country*) of residence: SE

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: (*Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.*)

L.A.GROTH & Co.KB
KARLSSON, Leif et al.
Box 6107
S-102 32 STOCKHOLM
Sweden

Telephone No. +46 - 8 - 729 91 00

Facsimile No. +46 - 8 - 31 67 67

Teleprinter No.

☐ Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. III **FURTHER APPLICANTS AND/OR (FURTHER) INVENTORS**

If none of the following sub-boxes is used, this sheet is not to be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.)*

GERTMAR, Lars
Humlegatan 6

S-722 26 VÄSTERÅS
Sweden

This person is:

☐ applicant only
☒ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: SE

State *(i.e. country)* of residence: SE

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.)*

BRANDT, Lennart
Vasagatan 26 B

S-722 15 VÄSTERÅS
Sweden

This person is:

☐ applicant only
☒ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: SE

State *(i.e. country)* of residence: SE

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.)*

This person is:

☐ applicant only
☐ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality:

State *(i.e. country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.)*

This person is:

☐ applicant only
☐ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality:

State *(i.e. country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

Regional Patent

☒ **AP** **ARIPO Patent:** KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SZ Swaziland, UG Uganda, and any other State which is a Contracting State of the Harare Protocol and of the PCT

☒ **EA** **Eurasian Patent:** AM Armenia, AZ Azerbaijan, BY Belarus, KG Kyrgyzstan, KZ Kazakstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT

☒ **EP** **European Patent:** AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, DE Germany, DK Denmark, ES Spain, FI Finland, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT

☒ **OA** **OAPI Patent:** BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* . . . .

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

☒ AL Albania
☒ AM Armenia
☒ AT Austria
☒ AU Australia
☒ AZ Azerbaijan
☒ BA Bosnia and Herzegovina
☒ BB Barbados
☒ BG Bulgaria
☒ BR Brazil
☒ BY Belarus
☒ CA Canada
☒ CH and LI Switzerland and Liechtenstein
☒ CN China
☒ CU Cuba
☒ CZ Czech Republic and utility model
☒ DE Germany and utility model
☒ DK Denmark and utility model
☒ EE Estonia
☒ ES Spain
☒ FI Finland and utility model
☒ GB United Kingdom
☒ GE Georgia
☒ HU Hungary
☒ IL Israel
☒ IS Iceland
☒ JP Japan
☒ KE Kenya
☒ KG Kyrgyzstan
☒ KP Democratic People's Republic of Korea
☒ KR Republic of Korea
☒ KZ Kazakstan
☒ LC Saint Lucia
☒ LK Sri Lanka
☒ LR Liberia
☒ LS Lesotho
☒ LT Lithuania
☒ LU Luxembourg
☒ LV Latvia
☒ MD Republic of Moldova
☒ MG Madagascar
☒ MK The former Yugoslav Republic of Macedonia
☒ MN Mongolia
☒ MW Malawi
☒ MX Mexico
☒ NO Norway
☒ NZ New Zealand
☒ PL Poland
☒ PT Portugal
☒ RO Romania
☒ RU Russian Federation
☒ SD Sudan
☒ SE Sweden
☒ SG Singapore
☒ SI Slovenia
☒ SK Slovakia
☒ TJ Tajikistan
☒ TM Turkmenistan
☒ TR Turkey
☒ TT Trinidad and Tobago
☒ UA Ukraine
☒ UG Uganda
☒ US United States of America
☒ UZ Uzbekistan
☒ VN Viet Nam

Check-boxes reserved for designating States (for the purposes of a national patent) which have become party to the PCT after issuance of this sheet:

☒ YU Jugoslavien (fr. 1997-02-01)
☒ GH Ghana (AP) (fr. 1997-02-26)
☐ . . . .
☐ . . . .

In addition to the designations made above, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except the designation(s) of __________
The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)*

Further priority claims are indicated in the Supplemental Box ☐

Box No. VI PRIORITY CLAIM

The priority of the following earlier application(s) is hereby claimed:

Country (in which, or for which, the application was filed)	Filing Date (day/month/year)	Application No.	Office of filing (only for regional or international application)
item (1) Sweden	29 May 1996 (29.05.1996)	9602079-7	
item (2)			
item (3)			

Mark the following check-box if the certified copy of the earlier application is to be issued by the Office which for the purposes of the present international application is the receiving Office (a fee may be required):

☒ The receiving Office is hereby requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s) : (1)

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(If two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):* ISA / SE

Earlier search *Fill in where a search (international, international-type or other) by the International Searching Authority has already been carried out or requested and the Authority is now requested to base the international search, to the extent possible, on the results of that earlier search. Identify such search or request either by reference to the relevant application (or the translation thereof) or by reference to the search request:*

Country (or regional Office):	Date *(day/month/year)*:	Number:
Sweden	29 May 1996	SE 96/00648

Box No. VIII CHECK LIST

This international application contains the following number of sheets:

1. request	:	4	sheets
2. description	:	10	sheets
3. claims	:	3	sheets
4. abstract	:	1	sheets
5. drawings	:	3	sheets
Total	:	21	sheets

This international application is accompanied by the item(s) marked below:

1. ☐ separate signed power of attorney
2. ☐ copy of general power of attorney
3. ☐ statement explaining lack of signature
4. ☐ priority document(s) identified in Box No. VI as item(s):
5. ☐ fee calculation sheet
6. ☐ separate indications concerning deposited microorganisms
7. ☐ nucleotide and/or amino acid sequence listing (diskette)
8. ☐ other *(specify)*:

Figure No. 2 of the drawings (if any) should accompany the abstract when it is published.

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

L.A.GROTH & Co.KB

Leif Karlsson

For receiving Office use only

1. Date of actual receipt of the purported international application:	
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:	
4. Date of timely receipt of the required corrections under PCT Article 11(2):	
5. International Searching Authority specified by the applicant: ISA /	6. ☐ Transmittal of search copy delayed until search fee is paid

2. Drawings:

☐ received:

☐ not received:

Inventor: LEIJON et al.
Total No. of Cases Entered: 39

X REFERENCES:	FREQ. CITED:
US 5646467 (EP 0677915 A1)	1
US 5311418 (WO 9107807 A1)	1
US 5365132	1
US 5341561	1
US 5111095	1
US 5067046	1
US 5066881	2
US 5036165	13
US 4853565	1
US 4745314	1
US 4429244	1
US 4425521	1
US 4208597	1
US 4200818	1
US 4184186	3
US 4109098	1
US 3447002	1
US 3437858	1
US 2217430	1

Y REFERENCES:	FREQ. CITED:
US 5452170	1
US 5325008	4
US 5153460	4
US 5140290	2
US 5094703	1
US 5036165	14
US 4853565	4
US 4745314	1
US 4692731	1
US 4594630	2
US 4523249	2
US 4429244	3
US 4425521	1
US 4208597	1
US 4200818	1
US 4184186	3
US 4164772	3
US 4134146	1
US 4109098	1
US 4008409	3
US 3943392	1
US 3932779	2
US 3891880	1
US 3447002	1
US 3444407	2
US 3437858	1
US 3418530	4
US 3158770	2
US 3130335	1
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US 2217430	1
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RELEVANT FOREIGN ARTS:	
BG 702892 A (ELECTRIC RAILWAY SYSTEM) 27 Jan 1954	1
DE 975999 C (SIEMENS-SCHUCKERTWERKE AKTIENGESELLSCHAFT, BERLIN UND ERLANGEN) 10 Jan 1963	1
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FR 2556146 A1 (SOCIETE DE PARIS ET DU RHONE) 7 June 1985	2
GB 937013 A (LICENTIA PATENT-VERWALTUNGS G.B.M.H) 18 Sep 1963	1
GB 853021 A (THE ENGLISH ELECTRIC CO. LTD.) 2 November 1960	1
GB 1135242 A (ASSOCIATED ELETRICAL INDUSTRIES LIMITED) 4 Dec 1968	2
SU 955369 A (GJK) 18 Nov 1997	1
SU 955369 A ((GIDR) SCI SECT GIDROPROEKT RES INST) 30 Aug 1982	3

952 779 5630

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H02K 3/40 — A1

(11) International Publication Number: WO 97/45925

(43) International Publication Date: 4 December 1997 (04.12.97)

(21) International Application Number: PCT/SE97/00887

(22) International Filing Date: 27 May 1997 (27.05.97)

(30) Priority Data: 9602079-7 29 May 1996 (29.05.96) SE

29 Nov 98/23 MRS

(71) Applicant (*for all designated States except US*): ASEA BROWN BOVERI AB [SE/SE]; S-721 83 Västerås (SE).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): LEIJON, Mats [SE/SE]; Hyvlargatan 5, S-723 35 Västerås (SE). GERTMAR, Lars [SE/SE]; Humlegatan 6, S-722 26 Västerås (SE). BRANDT, Lennart [SE/SE]; Vasagatan 26B, S-722 15 Västerås (SE).

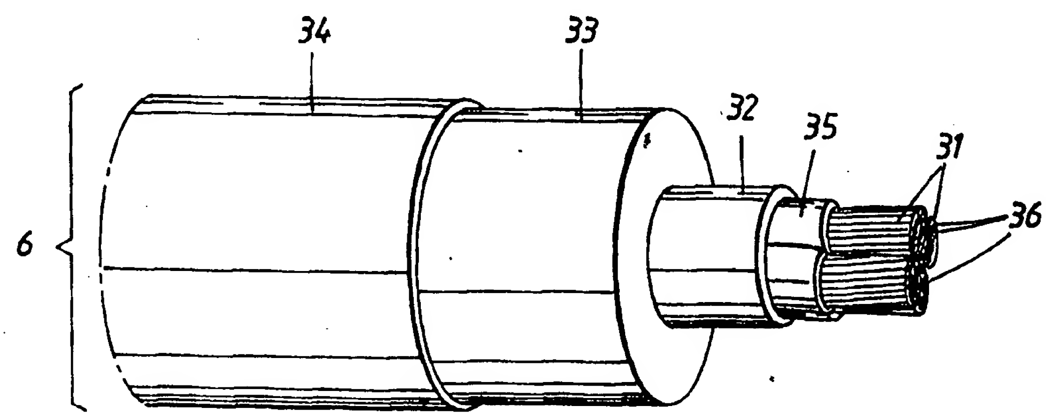
(74) Agent: KARLSSON, Leif; L.A. Groth & Co. KB, P.O. Box 6107, S-102 32 Stockholm (SE).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, ES, FI, FI (Utility model), GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

Received Ceylon ...

(54) Title: HIGH-VOLTAGE PLANTS WITH ELECTRIC MOTORS



(57) Abstract

In a plant comprising one or more electric machines constructed with insulated conductors and connected for heavy current via insulated conductors, the magnetic circuit in at least one of these electric machines is connected directly to a high supply voltage of 20 - 800 kV, preferably higher than 36 kV. The insulation of the electric machine is built up of a cable (6) placed in its winding and comprising one or more current-carrying conductors (31) with a number of strands (36) surrounded by outer and inner semiconducting layers (34, 32) and intermediate insulating layers (33). The conductors (31) may be group-wise connected in parallel and semiconducting layers are therefore not required around every conductor in the group. If the conductors (31) are connected in series with each other within the group a part insulation (35) is required which will withstand a few kV, whereas connection of the conductors (31) to every phase requires a strong part insulation (35) which will withstand the phase voltage of the high-voltage supply network.

HIGH-VOLTAGE PLANTS WITH ELECTRIC MOTORS

Technical field:

The present invention relates to electric plants comprising motors intended for connection to distribution or transmission networks, hereinafter termed power networks. The invention relates secondly to a motor intended for use in such a plant. The motors may be either synchronous or asynchronous motors.

The plant with electric motors may be a rolling mill, paper mill, pulp drying machine, mine plant, quay structure, fan, pump or compressor systems, hoisting means, traverse, crane, centrifuge, conveyor, workshop plant, steel mills, etc. Plants with electric motors shall thus be understood in their widest sense.

Background art:

The magnetic circuits in electric motors usually comprise a laminated core, e.g. of sheet steel with a welded construction. To provide ventilation and cooling the core is often divided into stacks with radial and/or axial ventilation ducts. For larger motors the laminations are punched out in segments which are attached to the frame of the machine, the laminated core being held together by pressure fingers and pressure rings. The winding is disposed in slots in the laminated core, the slots generally having a cross section in the shape of a rectangle or trapezium.

In multi-phase electric motors the windings are made as either single or double layer windings. With single layer windings there is only one coil side per slot, whereas with double layer windings there are two coil sides per slot. By coil side is meant one or more conductors combined vertically or horizontally and provided with a common coil insulation, i.e. an insulation designed to withstand the rated voltage of the motor to earth.

Double-layer windings are generally made as diamond windings whereas single layer windings in the present context can be made as diamond or flat windings. Only one (possibly two) coil width exists in diamond windings whereas flat windings are made as concentric windings, i.e. with widely varying coil width. By coil width is meant the distance in arc dimension between two coil sides pertaining to the same coil.

Normally all large motors are made with double-layer winding and coils of the same size. Each coil is placed with one side in one

layer and the other side in the other layer. This means that all coils cross each other in the coil end. If there are more than two layers these crossings complicate the winding work and the coil end is less satisfactory.

It is considered that coils for rotating electric motors can be manufactured with good results up to a voltage range of 10 - 20 kV.

Large alternating current motors are divided into synchronous and asynchronous motors, the former generally covering a higher power range up to a few tens of MW and being constructed to be supplied with a voltage of normally maximally 20 kV. The synchronous motor operates with a rotor speed that is synchronous with the network frequency. In an asynchronous motor the magnetic field rotates faster than the rotor so that the induced currents will provide torque in the direction of rotation. The two types of motors are to a great extent similar in construction. They consist of a stator with a rotor placed inside the stator. The stator is built up of a laminated core with slots punched out for the winding. The stator is placed in a bottom box attached to the foundation by its feet. The rotor is suspended in bearings mounted on the box. A stator shell is placed on the bottom box to protect the active parts. The shell is provided with openings for cooling air to enter.

The function of an alternating current motor is based on interaction between magnetic fields, electric currents and mechanical motion. The magnetic fields are localized primarily in the iron of the machine and the electric currents are localized in the windings.

A distinction is made between two main types of alternating current motors: synchronous and asynchronous machines. The principal difference between synchronous and asynchronous machines is how the torque is produced. A synchronous motor is excited by supplying energy to the rotor from the outside via brushless exciters or slip rings, whereas an asynchronous motor obtains its excitation energy from the stator current through induction. The speed of the synchronous motor is therefore not as dependent on load as in the asynchronous motor.

Depending on the construction of the rotor, there are two types of synchronous motors: those with salient poles and those with a cylindrical rotor. In high-speed 2-pole operation the mechanical stresses on the rotor will be extremely high and in that case it is favourable to use a cylindrical rotor. For motors with lower speeds, four-pole or more, the rotor diameter will be larger. In

view of the lower speed and thus correspondingly lower mechanical stresses, it is more favourable for the rotor to have salient poles.

The boundary between the two types is indefinite. At higher power and with four poles, cylindrical rotors are used that are long and slim in shape. At lower power and with four poles, rotors with salient poles are used.

Asynchronous motors are also divided into two types: squirrel-cage induction motors or slip ring motors. Common to both types is that the rotor is built up of laminations with slots for the rotor winding. The difference is in the construction of the winding. The squirrel-cage induction motors have a squirrel-cage winding consisting of axial rods that are short-circuited at the ends with a short-circuiting ring. Asynchronous motors with slip rings have a three-phase winding in the rotor with phase terminals connected to the slip rings.

By designing the rotor slots in various ways the start and operating properties of the squirrel-cage induction motor can be adjusted to various operating requirements. Slip-ring asynchronous motors are primarily used under difficult starting conditions. External resistance can be connected via the slip rings. By increasing the rotor resistance the maximum torque can be moved towards lower speed, thus increasing the start torque. When starting is complete the external start resistance is short-circuited.

The choice of a large alternating current motor as regards to type, nesting class and cooling method, is dependent on the following factors, among others:

- Torque characteristic of the load
- Type of load and load cycle
- Start power restrictions
- Network characteristics
- Cost of electric energy
- Environment where the motor is to be installed
- Investment cost in relation to the estimated service life of the plant

The main desire for an electric machine is that its capital cost and running costs shall be as low as possible. It is therefore desirable to keep the efficiency as high as possible at given power

factors. The synchronous motor generally has higher efficiency than the asynchronous motor.

The rotor of a synchronous motor is often manufactured with salient poles. Its main use is in the power range of 1 MW to a few tens of MW, e.g. for grinding mills and refiners in the paper industry, for large pumps both in the process industry and in connection with weak networks, e.g. for irrigation installations in desert countries. The oil industry also uses large synchronous motors for pumps and compressors.

The main reason for using synchronous motors instead of the less expensive asynchronous motors is that the synchronous motor produces less stress on the network, in the form of lower start current, and that at over-excitation the synchronous motor can also be used to improve the power factor. Large synchronous motors may also have slightly higher efficiency than equivalent asynchronous motors.

The winding must be insulated, both between the winding turns in the coil and also between coil and surroundings. Various forms of plastic, varnish and glassfibre material are often used as insulating material. The coil ends are braced in order to counteract the forces appearing between the various coils, particularly at short-circuiting.

Motors of the type described above are connected to high-voltage networks of e.g. 145 kV through the use of a transformer which lowers the voltage. The use of a motor in this way, connected to the high-voltage network via a transformer entails a number of drawbacks. Among others the following drawbacks may be mentioned.

- the transformer is expensive, increases transport costs and requires space
- the transformer lowers the efficiency of the system
- the transformer consumes reactive power
- a conventional transformer contains oil, with the associated risks
- involves sensitive operation since the motor, via the transformer, works against a weaker network.

Description of the invention:

An object of the invention is therefore to enable the use of one or more electric motors in a plant which is directly connected to high-voltage supply networks, by which is meant here sub-

transmission and distribution networks without intermediate connection of a transformer.

The benefit gained by attaining the above-mentioned object is the avoidance of an intermediate oil-filled transformer, the reactance of which otherwise consumes reactive power.

This object is achieved according to the invention in that a plant of the type described in the preamble to claim 1 is given the special features defined in the characterizing part of this claim., and in that an electric motor of the type described in the preamble to claim 25 is given the special features defined in the characterizing part of this claim.

Thanks to the specially produced solid insulation, the motors in such a plant can be supplied directly with a voltage level considerably in excess of what is possible using known technology, and at a voltage that may reach the highest applicable voltages for high-voltage power networks.

The advantage is thus gained that the transformer becomes superfluous, therefore eliminating all the problems touched upon above that are inherent with a plant in which the voltage must be stepped down, as well as other significant advantages. With a plant according to the invention the overload capacity is also radically increased. This may be +100 % for an hour or two, enabling motors with lower rated output to be selected, thereby also saving expense.

Higher output is also obtained through a high voltage on the motors since this is proportional to the voltage squared. The invention thus enables electric motors with higher power to be achieved. The invention thus extends the application area for electric machines to the range 1-300 MW and even enables applications at still higher power levels.

The major and essential difference between known technology and the embodiment according to the invention is thus that this is achieved with a magnetic circuit included in at least one electric motor which is arranged to be directly connected to a high supply voltage via coupling elements such as breakers and isolators. The magnetic circuit thus comprises one or more laminated cores. The winding consists of a threaded cable with one or more permanently insulated conductors having a semiconducting layer both at the conductor and outside the insulation, the outer semiconducting layer being connected to earth potential.

To solve the problems arising with direct connection of electric motors, both rotating and static motors, to all types of high-voltage power networks, at least one motor in the plant according to the invention has a number of features as mentioned above, which differ distinctly from known technology. Additional features and further embodiments are defined in the dependent claims and are discussed in the following.

The features mentioned above and other essential characteristics of the plant and at least one of the electric motors included therein according to the invention, include the following:

- The winding is produced from a cable having one or more permanently insulated conductors with a semiconducting layer at both conductor and sheath. Some typical conductors of this type are PEX cable or a cable with EP rubber insulation which, however, for the present purpose are further developed both as regards the strands in the conductor and the nature of the outer sheath. PEX = crosslinked polyethylene (XLPE). EP = ethylene propylene.

- Cables with circular cross section are preferred, but cables with some other cross section may be used in order to obtain better packing density, for instance.

- Such a cable allows the laminated core to be designed according to the invention in a new and optimal way as regards slots and teeth.

- The winding is preferably manufactured with insulation in steps for best utilization of the laminated core.

- The winding is preferably manufactured as a multi-layered, concentric cable winding, thus enabling the number of coil-end intersections to be reduced.

- The slot design is suited to the cross section of the winding cable so that the slots are in the form of a number of cylindrical openings running axially and/or radially outside each other and having an open waist running between the layers of the stator winding.

- The design of the slots is adjusted to the relevant cable cross section and to the stepped insulation of the winding. The stepped insulation allows the magnetic core to have substantially constant tooth width, irrespective of the radial extension.

- The above-mentioned further development as regards the strands entails the winding conductors consisting of a number of impacted strata/layers, i.e. insulated strands that from the point

of view of an electric machine, are not necessarily correctly transposed, uninsulated and/or insulated from each other.

• The above-mentioned further development as regards the outer sheath entails that at suitable points along the length of the conductor, the outer sheath is cut off, each cut partial length being connected directly to earth potential.

The use of a cable of the type described above allows the entire length of the outer sheath of the winding, as well as other parts of the plant, to be kept at earth potential. An important advantage is that the electric field is close to zero within the coil-end region outside the outer semiconducting layer. With earth potential on the outer sheath the electric field need not be controlled. This means that no field concentrations will occur either in the core, in the coil-end regions or in the transition between them.

The mixture of insulated and/or uninsulated impacted strands, or transposed strands, results in low stray losses.

The cable for high voltage used in the winding is constructed of an inner core/conductor with a plurality of strands, at least two semiconducting layers, the innermost being surrounded by an insulating layer, which is in turn surrounded by an outer semiconducting layer having an outer diameter in the order of 10-250 mm and a conductor area in the order of 40-3000 mm^2.

If at least one of the motors in the plant according to the invention is constructed in the manner specified, start and control of this motor or these motors can be achieved with the start methods, known per se, described by way of example in the literature discussed in the introduction.

According to a particularly preferred embodiment of the invention, at least two of these layers, preferably all three, have the same coefficient of thermal expansion. The decisive benefit is thus gained that defects, cracks and the like are avoided during thermal movement in the winding.

According to another important preferred embodiment of the invention at least one of the motors in the plant has one or more connection voltages.

From another aspect of the invention, the object stated has been achieved in that a plant of the type described in the preamble to claim 23 is given the special features defined in the characterizing part of this claim.

Since the insulation system, suitably permanent, is designed so that from the thermal and electrical point of view it is dimensioned for over 36 kV, the plant can be connected to high-voltage power networks without any intermediate step-down transformer, thereby achieving the advantages referred to. Such a plant is preferably, but not necessarily, constructed to include the features defined for plants as claimed in any of claims 1-22.

The above-mentioned and other advantageous embodiments of the invention are defined in the dependent claims.

Brief description of the drawings:

The invention will be described in more detail in the following detailed description of a preferred embodiment of the construction of the magnetic circuit of an electric motor in the plant, with reference to the accompanying drawings in which

Figure 1 shows a schematic axial end view of a sector of the stator in an electric motor in the plant according to the invention,

Figure 2 shows an end view, step-stripped, of a cable used in the winding of the stator according to Figure 1, and

Figures 3-7 show examples of different start circuits known per se.

Description of a preferred embodiment:

In the schematic axial view through a sector of the stator 1 according to Figure 1, pertaining to the electric motor or motors included in the plant, the rotor 2 of the motor is also indicated. The stator 1 is composed in conventional manner of a laminated core. Figure 1 shows a sector of the motor corresponding to one pole pitch. From a yoke part 3 of the core situated radially outermost, a number of teeth 4 extend radially in towards the rotor 2 and are separated by slots 5 in which the stator winding is arranged. Cables 6 forming this stator winding, are high-voltage cables which may be of substantially the same type as those used for power distribution, i.e. PEX cables. One difference is that the outer, mechanically-protective sheath, and the metal screen normally surrounding such power distribution cables are eliminated so that the cable for the present application comprises only the conductor and at least one semiconducting layer on each side of an insulating layer. Thus, the semiconducting layer which is sensitive to mechanical damage lies naked on the surface of the cable.

The cables 6 are illustrated schematically in Figure 1, only the conducting central part of each cable part or coil side being drawn in. As can be seen, each slot 5 has varying cross section with alternating wide parts 7 and narrow parts 8. The wide parts 7 are substantially circular and surround the cabling, the waist parts between these forming narrow parts 8. The waist parts serve to radially fix the position of each cable. The cross section of the slot 5 also narrows radially inwards. This is because the voltage on the cable parts is lower the closer to the radially inner part of the stator 1 they are situated. Slimmer cabling can therefore be used there, whereas coarser cabling is necessary further out. In the example illustrated cables of three different dimensions are used, arranged in three correspondingly dimensioned sections 51, 52, 53 of slots 5.

Figure 2 shows a step-wise stripped end view of a high-voltage cable for use in an electric motor according to the present invention. The high-voltage cable 6 comprises one or more conductors 31, each of which comprises a number of strands 36 which together give a circular cross section of copper (Cu), for instance. These conductors 31 are arranged in the middle of the high-voltage cable 6 and are surrounded in the embodiment shown by a part insulation 35. However, it is feasible for the part insulation 35 to be omitted on one of the conductors 31. In the present embodiment of the invention the conductors 31 are together surrounded by a first semiconducting layer 32. Around this first semiconducting layer 32 is an insulating layer 33, e.g. PEX insulation, which is in turn surrounded by a second semiconducting layer 34. Thus the concept "high-voltage cable" in this application need not include any metallic screen or outer sheath of the type that normally surrounds such a cable for power distribution.

Figures 3-7, in the form of basic diagrams, show examples of known start procedures applicable to rotating motors in the plant according to the present invention. The following designations are used in the figures:

U:	High-voltage network	X_t	Transformer impedance
X_n	Network impedance	R:	Reactor
B:	Breaker	X_r	Reactor impedance
M:	Motor	C:	Capacitor
X_m	Motor impedance	X_c	Capacitor impedance

T: Transformer L: 3-phase stator windings

Figure 3 thus relates to the procedure for transformer start, Figure 4 to the procedure for reactor start, Figure 5 to the procedure for part-winding start, Figure 6 to the procedure for capacitor start, and Figure 7 to the procedure for combined reactor and capacitor start. Other combinations of start procedures are of course also applicable in the plant according to the invention. The various start procedures are described in the literature, e.g. in the literature references mentioned in the introduction of this application.

Thus, with one or more rotating electric motors constructed in accordance with the invention, industrial plants comprising one or more such motors can be connected directly to high-voltage supply networks, i.e. networks having supply voltages of 20 kV or higher, thereby enabling the eliminated of at least one transformer.

Using permanent insulating power cable according to the invention, between the electric motors included in the plant, and achieving a compact siting of these motors thus ensures that the electric fields are small and bushings/terminals can be entirely eliminated.

CLAIMS

1. An electric plant for high voltage consisting of one or more motors, each comprising at least one winding, characterized in that the winding of at least one of the electric motors comprises an insulation system comprising at least two semiconducting layers, each layer constituting essentially an equipotential surface, and intermediate solid insulation between the layers.

2. A plant as claimed in claim 1, characterized in that at least one motor has one or more connection voltages.

3. A plant as claimed in claim 1 or 2, characterized in that at least one of the layers has substantially the same coefficient of thermal expansion as the solid insulation.

4. A plant as claimed in any of claims 1-3, characterized in that all transformation of substantial power is arranged to take place in the same electric motor.

5. A plant as claimed in any of claims 1-4, characterized in that the insulation is built up of a cable (6) intended for high voltage, comprising one or more current-carrying conductors (31) surrounded by at least two semiconducting layers (32, 34) with intermediate insulating layers (33) of solid insulation.

6. A plant as claimed in claim 5, characterized in that the innermost semiconducting layer (32) is at substantially the same potential as the conductor(s) (31).

7. A plant as claimed in either claim 5 or claim 6, characterized in that one of the outer semiconducting layers (34) is arranged to form essentially an equipotential surface surrounding the conductor(s) (31).

8. A plant as claimed in claim 7, characterized in that said outer semiconducting layer (34) is connected to a predefined potential.

9. A plant as claimed in claim 8, characterized in that the predefined potential is earth potential.

10. A plant as claimed in any of claims 5-9, characterized in that at least two of said layers have substantially the same coefficient of thermal expansion.

11. A plant as claimed in any of claims 5-7, characterized in that the current-carrying conductor comprises a plurality of strands, only a few of the strands not being insulated from each other.

12. A plant as claimed in any of claims 1-11, characterized in that the winding consists of a cable comprising one or more current-carrying conductors (2), each conductor consisting of a number of strands, an inner semiconducting layer (3) being arranged around each conductor, an insulating layer (4) of solid insulation being arranged around each inner semiconducting layer (3) and an outer semiconducting layer (5) being arranged around each insulating layer (4).

13. A plant as claimed in claim 12, characterized in that the cable also comprises a metal screen and a sheath.

14. A plant as claimed in any of the preceding claims, characterized in that the stator of the motor is cooled at earth potential by means of a flow of gas and/or liquid.

15. A plant as claimed in any of the preceding claims, characterized in that the high-voltage cables (6) have a conductor area of between 40 and 3000 mm^2 and have an outer cable diameter of between 10 and 250 mm.

16. A plant as claimed in any of the preceding claims, characterized in that the start current and/or fault or current for the rotating electric motor(s) is arranged to be limited by an electric static machine, i.e. a reactor/inductor, which is temporarily and/or permanently connected in series with the armature winding of the rotating electric machine (Figure 4).

17. A plant as claimed in any of the preceding claims, characterized in that the neutral point of at least one motor is earthed via an impedance.

18. A plant as claimed in any of the preceding claims, characterized in that the neutral point of at least one motor is directly connected to earth.

19. A plant as claimed in any of the preceding claims, characterized in that the motor is arranged to operate as producer of reactive power with temporarily large overload capacity.

20. A plant as claimed in any of the preceding claims, characterized in that the motor is arranged to be connected to a distribution network or transmission network via

coupling elements and without any step-down transforming of the voltage level.

21. A plant as claimed in any of the preceding claims, characterized in that the motor is arranged to be connected to a distribution network or transmission network having a supply voltage in excess of 36 kV.

22. A plant as claimed in any of the preceding claims, characterized in that the winding of the motor is arranged for self-regulating field control and lacks auxiliary means for control of the field.

23. An electric plant for high voltage consisting of one or more motors, each of which comprises at least one winding, characterized in that the winding of at least one of the electric motors comprises an insulation system which, as regards its thermal and electrical properties, permits a voltage level in excess of 36 kV.

24. An electric plant as claimed in claim 23, characterized in that said motors includes the features defining the plant claimed in any of claims 1-21.

25. An electric motor comprising at least one winding, characterized in that the winding comprises an insulation layer including at least two semiconducting layers, each semi-conductor layer constituting essentially an equipotential surface, and intermediate solid insulation.

26. A motor as claimed in claim 25, characterized in that its stator winding is divided into two parts in order to achieve partial winding start.

27. A motor as claimed in claim 25 or claim 26, characterized in that it has one or more connection voltages.

28. A motor as claimed in any of claims 25-27, characterized in that it includes the features defined for the motor in the plant as claimed in any of claims 2-24.

Fig-1

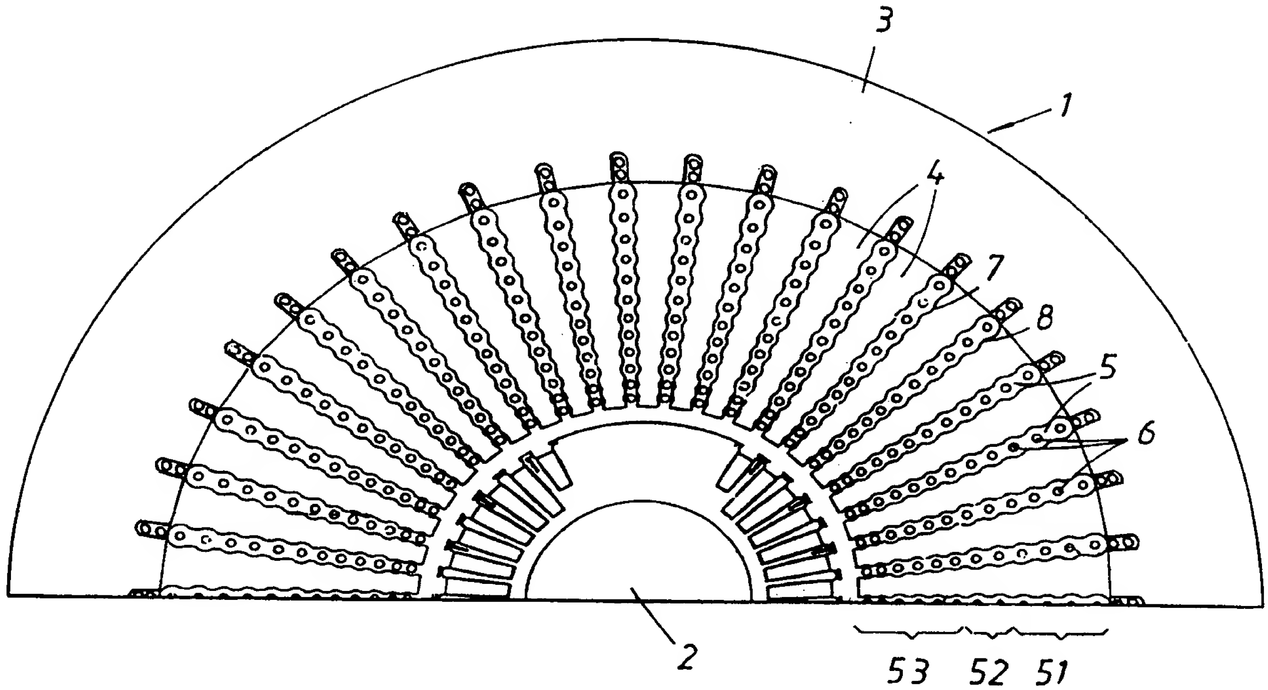


Fig-2

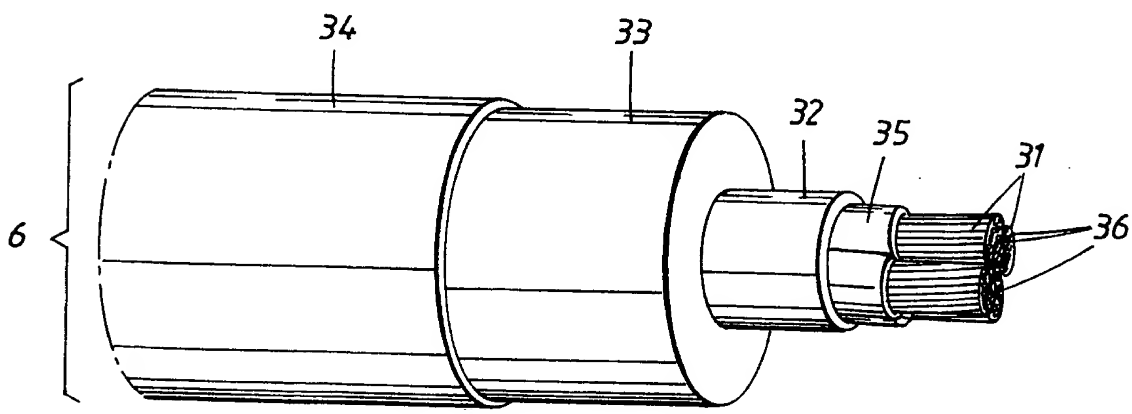


Fig. 3

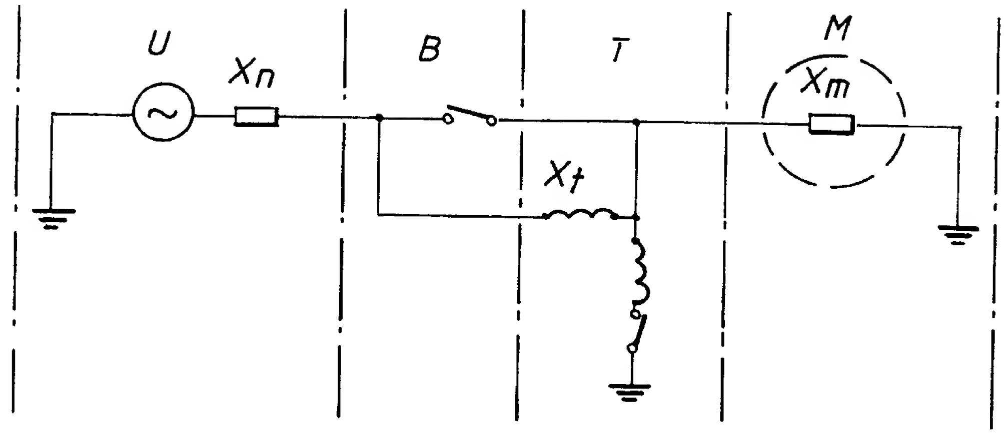


Fig. 4

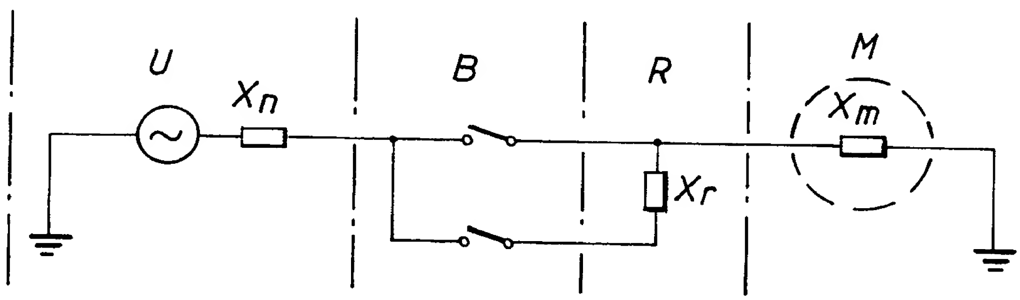


Fig. 6

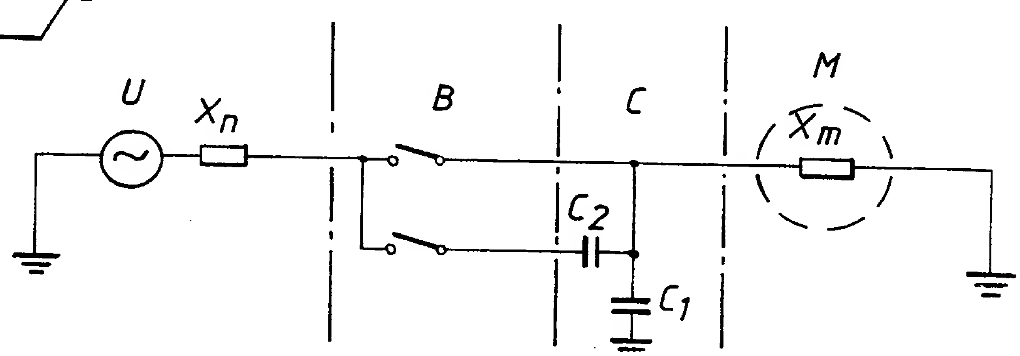


Fig. 5

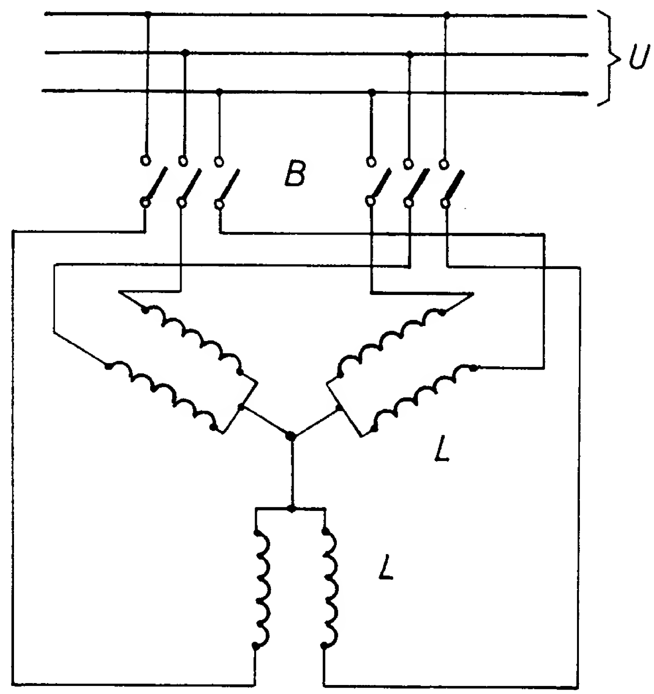
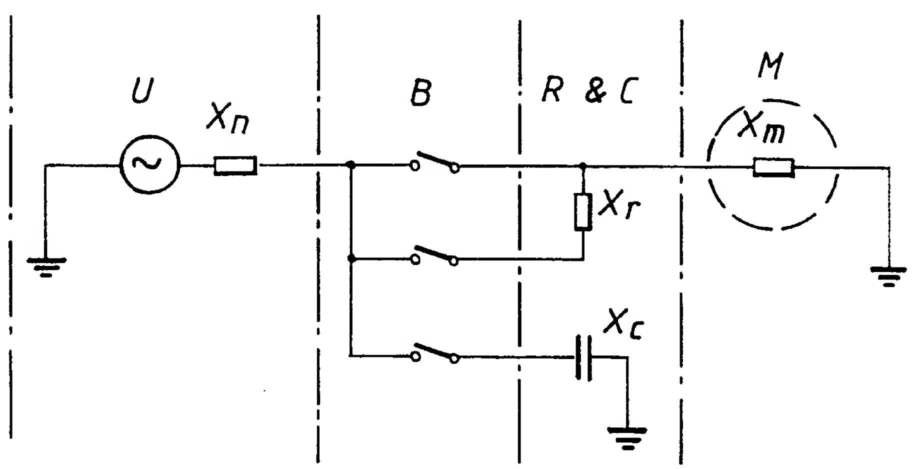


Fig. 7



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Information on patent family members

01/09/97

International application No.
PCT/SE 97/00887

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US 08952995OOP1

Creation date: 15-05-2003
Indexing Officer: LCHAU - LINH CHAU
Team: CENTRALSCANPRINT
Dossier: 08952995

Legal Date: 02-02-1999

No.	Doccode	Number of pages
1	IMIS	1

Total number of pages: 1

Remarks:

Order of re-scan issued on ....